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# Perspectives on wind turbine noise

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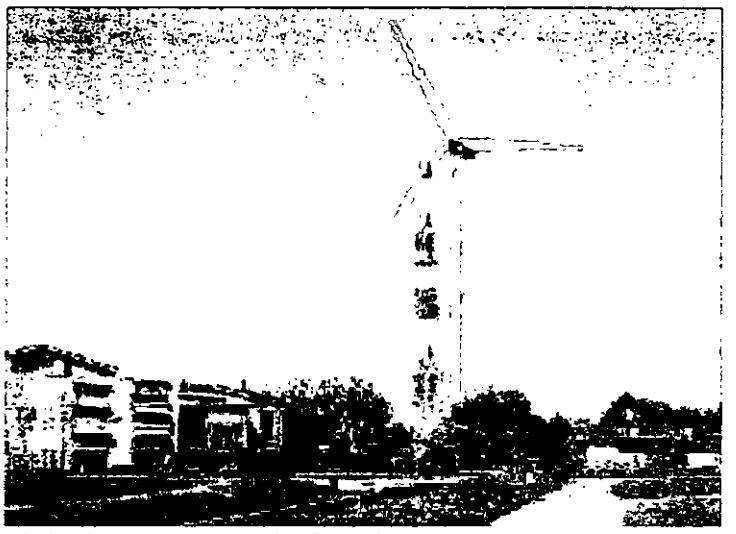
When the planning of a wind farm is in public debate, different perspectives are often used without people being aware of them. Just look at websites of opponents and proponents with wind turbines towering over buildings in the background or distant turbines seen from a pleasant foreground.



*Wind turbine compared to 2 church steeples.*

According to the British Wind Energy Association "well designed wind turbines are generally quiet in operation, and compared to the noise of road traffic, trains, aircraft, and construction activities, to name but a few, the noise from wind turbines is very low. Outside the nearest houses, which are at least 300 meters away, and more often further, the sound of a wind turbine generating electricity is likely to be about the same level as noise from a flowing stream about 50-100 meters away or the noise of leaves rustling in a gentle breeze," whereas critic Pierpont states that "the noise produced by wind turbines has a thumping, pulsing character, especially at night, when it is more audible. The noise is louder at night because of the contrast between the still, cool air at ground level and the steady stream of wind at the level of the turbine hubs. This nighttime noise travels a long distance. It has been documented to be disturbing to residents 1.2 miles away from wind turbines in regular rolling terrain, and 1.5 miles away in Appalachian valleys."

The different notions are, in part, a result of the perspective of a person or an organization. The recent WINDFARM perception study has shown that annoyance from the sound of wind turbines is related to attitude towards wind energy and/or wind turbines in the landscape, and to the visibility of a wind farm. Also, residents who had economic benefits from wind turbines were hardly or not annoyed, while for residents without such benefits the sound from wind turbines is more annoying than sound at the same level from major noise sources such as road, rail, or air traffic, and industry.

TNO (Organization for Applied Research) researchers have determined dose-response curves for wind turbine noise from all relevant studies. The results are shown in Fig. 1 for all respondents that did not have economic benefits from wind turbines. At left the results are plotted when annoyance or severe annoyance (as perceived either indoors or outdoors) is the response and at the right when sleep disturbance (being awakened by sound at least once a month) is the response. Here the dose level (noise exposure) is the outdoor sound level in Lden (time weighted average of daytime, evening and night time) or Lnight; Lden is 4.7 dB higher and Lnight 1.6 dB lower than the sound level would be with a 8 m/s wind speed at 10 m in a 'standard' atmosphere (*i.e.*, of neutral stability).

When compared to other noise sources the degree of annoyance of sound from wind turbines is surprisingly high. Major noise sources (road, rail, and air traffic, industry) in general do not cause severe annoyance below 42 dB(A). At 50 dB(A) 6% or less of the exposed residents are highly annoyed, whereas for wind turbines, severe annoyance (indoors) occurs at lower levels below 40 dB(A) and at 50 dB(A) has risen to 14.5% of the exposed and non-benefiting population. A clue to explain this could be the similarity with the high annoyance associated with the noise from shunting yards. Whereas most noise sources are

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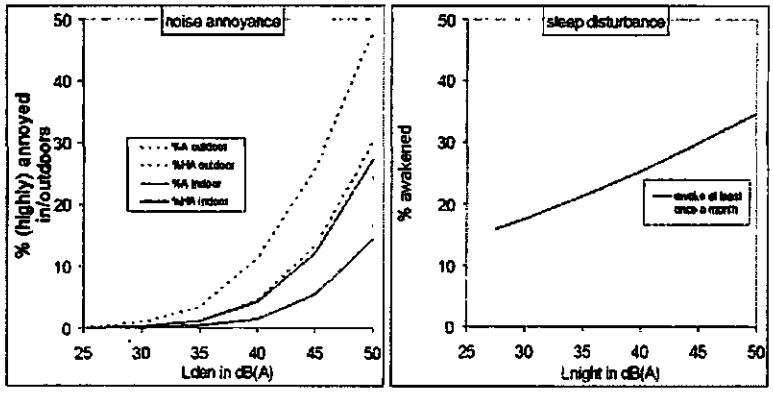


*Fig. 1. Percentage of residents annoyed (left) or disturbed in sleep (right) in relation to the sound level due to wind turbines over all time (Lden) or night (Lnight).*

less active at night, shunting yards often are not and the clanking and engine noise is even more audible in the relative quiet of the evening and night. Four out of ten residents find wind turbines louder at night than in daytime and another four do not find it clearly different. For an inland as well as a coastal location a 60 m high wind turbine produces the same sound level at any time of the day or night, when averaged over a long period. Higher wind turbines are actually louder at night than they are in day time, though the difference is small (0.5 dB at 100-120 m hub height). Neighbors of modern wind turbines have learned to distinguish between a 'high wind' driving the turbine and a 'low wind' that they feel themselves, and notice that these winds can be quite different after sundown. This phenomenon–in a partly cloudy or clear sky the near-ground wind often subsides at sundown while the higher altitude wind picks up at the same time–is well known in meteorology and atmospheric physics but was considered insignificant for wind turbines.

A second explanation for the intrusiveness of wind turbine sound may be its character, the beating or thumping that may have the same effect, drawing attention, as the clanking noise from shunting trains. When asked what a wind farm sounds like, three out of four residents think that swishing or lashing is a proper description. The modulation of the sound level at the blade passing frequency (approximately once a second for modern wind turbines at high speed) can be explained by the change in wind speed over the rotor area which is higher at night than it is in daytime. It can also be caused by an obstacle (such as another turbine) upwind from a turbine. It can be shown that the modulation depth (the variation in sound level) due to altitude dependent wind speed differences can increase to 5–6 dB, and even up to ~9 dB when the modulations from several turbines are in phase and the 'thumps' from different turbines arrive at the same time. Human beings are sensitive to modulations with a frequency of the order of 1 Hz as it occurs in speech (periodicity of syllables) and musical rhythm. The beeps of a truck in reverse gear have the same periodicity.

It is interesting that a modulation of the sound level can also be observed close to a wind turbine: when standing very close to a wind turbine one can hear the swishing of the downward moving blades. This has been shown to be caused by the directivity of the blade as a noise source (more in the forward direction) and of Doppler amplification (the blade tip moves at ~ Mach 0.2). However, this explanation does not hold for a distant observer upwind or downwind from a turbine as the blades then have no changing velocity component in the direction of the observer.

It can be concluded that research in the last half decade has given a new perspective on the impact of wind turbines. This is especially true at night, a time at which measurements usually were not performed. Sound from modern, tall wind turbines does not abate at night and it is not always a soft, noisy sound (as it may be in daytime), but can at night attract attention because of its rhythm and the contrast with a quiet environment. Proponents tend to present wind turbines as they are heard in daytime, opponents mostly use the impact they cause during the evening and night. It seems wise to me to acknowledge the visual and aural intrusion, not deny it with NIMBY ("not in my back yard") arguments that only reinforce opposition. An improvement in the assessment of the sound level will be to take into account a realistic atmosphere and a possible penalty for the amplitude modulation. A significant non-acoustical measure to reduce noise annoyance may be to involve neighboring residents in the planning of a wind farm: instead of giving them the burden of nuisance, they could share in the benefits.

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